THE STATUS OF BAT ROOSTS IN CAVES IN THE SOUTH WEST OF WESTERN AUSTRALIA, WITH A FOCUS ON QUININUP LAKE CAVE

By KYLE N. ARMSTRONG (kyle@inet.museum.kyoto-u.ac.jp),
RIC BROWN*
and PETER ARMSTRONG
(petercolleen@upnaway.com)

Speleological Research Group of Western Australia.
* *Posthumously*

ABSTRACT

Caves suitable for bat habitation are relatively uncommon in the south west of Western Australia. We made regular observations of one of the largest known colonies of bats (*Chalinolobus morio*, Vespertilionidae) in Quininup Lake Cave near Cowaramup to determine if colony size and position within the cave changed seasonally, and whether such patterns had implications for their effective management. In addition, we investigated the occurrence of bats in other south west caves (in the Leeuwin – Naturaliste Ridge, and between Perth and Dongara) through a literature review as a context within which to determine the importance of the Quininup Lake Cave as a roost for bats. The Quininup Lake Cave is one of five caves in this area known to contain bats on a yearly basis. Thus, bats actually occupy much fewer caves that what appears to be available. Several types of disturbance were identified as threats to bat colonies in some of these caves, and we recommend several actions. It is hoped that a comprehensive plan for managing these colonies is adopted in the future.

INTRODUCTION

The Leeuwin – Naturaliste Ridge, south of Perth, comprises a block of granite-gneiss capped by soft Tamala limestone, which is extensively eroded into caves. Caves are most prolific around Witchcliffe, but also occur near Augusta, Cowaramup, Margaret River and Yallingup. Cave development is essentially absent from the rest of the south west corner of Western Australia, with the nearest limestone cave terrains to be found between Perth and Dongara, and on the

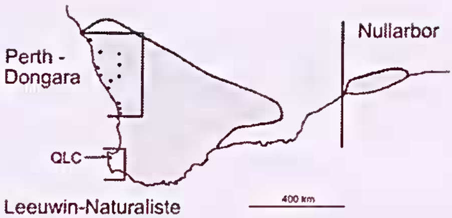

Figure 1. Location of Quininup Lake Cave (QLC), and the three regions considered in the present study for cave-roosting bats. Major towns in the Perth – Dongara region are indicated, which correspond to the locations of caves in Bridge (1975). The approximate distribution of the chocolate wattled bat *Chalinolobus morio* is shaded (data from FaunaBase, Western Australian Museum).

Nullarbor (Bridge 1975; Figure 1). Many of the caves are popular for recreational cavers, and some are considered important for their ethnographical, palaeontological, biological and geological features (Matthews 1985).

Colonies, as well as occurrences of smaller numbers of bats, have been observed in some of these caves, particularly the area between Perth and Dongara. Many contain subfossil guano and skeletal deposits of the ghost bat *Macroderma gigas* (Megadermatidae; Lundelius 1957, 1960; Cook 1960; Douglas 1967; Bridge 1975; Baynes *et al.* 1976), which is now extinct south of the Pilbara region (Molnar *et al.* 1984; Churchill and Helman 1990). Some of the vespertilionid bat colonies in caves north of Perth (e.g. Drovers and Yanchep Caves) have suffered declines or totally disappeared in the last 150 years as well. While the decline of *M. gigas* had probably already begun before European settlement (Molnar *et al.* 1984; Churchill and Helman 1990), the vespertilionid declines are more likely to be the result of human disturbance and inappropriate gating (R. Webb pers. comm.; K.N. Armstrong pers. obs.).

Given such intimations of the rarity of bats in south west caves, their apparent declines, and the popularity of caving in close proximity to Perth, it was recognised that a strategy for managing south west bat colonies would need to be based on historical and scientific information. To address this, the present study compiled what little information there is available on the occurrence of bats in caves of the Leeuwin – Naturaliste Ridge and Perth – Dongara region. A particular focus was given to the Quininup Lake Cave near Cowaramup (Figure 1), since it is believed to be the only cave currently inhabited by bats in the Leeuwin – Naturaliste Ridge, and the wider south west forested region. Trips conducted by the Speleological Research Group of Western Australia (SRGWA) recorded a colony of bats in this cave on three occasions between May 1998 and July 1999, however counts were not made. A total of 12 bats was observed in August 2001 by SRGWA and bats were observed to number "in the hundreds" during a Caves Management Advisory Committee (CMAC) trip in early 2002.

The Quininup Lake Cave is subject to a carefully controlled number of authorised visits by cavers and many unauthorised visits by members of the public, including in the summer months when the bats are thought to breed. The impact of such visits on the colony is largely unknown, however vandalism is common in the cave, and a new carpark constructed in 1999 to allow visitor access to the nearby beach has brought the cave entrance within view of the public. In 1990, a project called Operation Jigsaw was undertaken by members of the Western Australian Speleological Group (WASG) to repair c. 60 broken stalagmites in the cave. Track marking has been established in this cave, which was undertaken with regard to the location of decorations but without detailed knowledge of the preferred bat roosting areas. The present study sought to determine:

1. the species of bat inhabiting the Quininup Lake Cave, approximate numbers, and seasonal fluctuations in numbers (over the period of one year);
2. the parts of the cave used by the bats;
3. the importance of the Quininup Lake Cave in terms of the number of other subterranean structures that currently support bats in the region; and
4. appropriate management strategies to minimise disturbance to the bats.

METHODS

Description of Quininup Lake Cave

The main entrance to Quininup Lake Cave faces the Indian Ocean and is fronted by a freshwater lake that is fed from an underground stream running through the lowest part of the cave. The distance to the ocean is c. 400 m. The area supports thick head-high coastal heath. The cave has two main chambers, each of which open into the main entrance / overhang. Both chambers have a second entrance: that of the north chamber is a doline, which continues down to the freshwater stream; that of the south chamber is a simple opening opposite the main entrance. Decorations are present in all parts, however the south chamber has a dusty floor (Figure 2).

Survey methods

Visits to the cave were made in 11 months between September 2002 and October 2003 (excluding October and November 2002, July and August 2003). The impact of visits to the bat colony was minimised: each visit lasted c. 1 hour, only a small group of up to three experienced cavers entered the cave at any one time, and low impact observation techniques were used to count

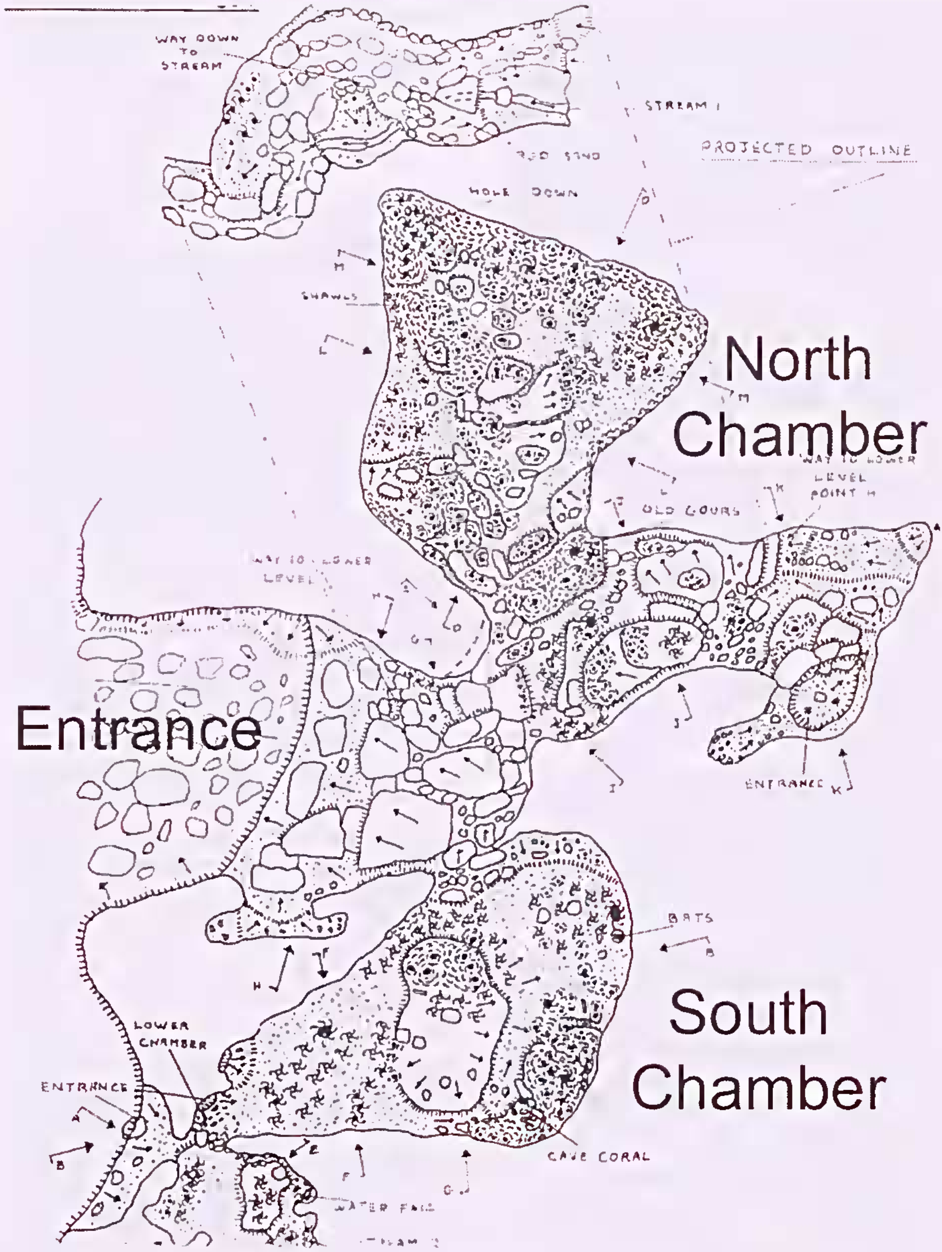

Figure 2. Quininup Lake Cave, with features mapped (surveyed and drawn by B. Loveday).

the number of bats in a cluster. Counts were made with a night vision scope using the infrared beam for illumination. Following that, a small number of photographs were taken with a flash. No bats were captured. Following counts of the main clusters, the remainder of the cave was searched thoroughly for other clusters and single individuals. The location of bat clusters was mapped in the cave using a map prepared by B. Loveday.

Identification to species was made by recording echolocation calls of bats exiting after sunset with an Anabat II bat detector system (Titley Electronics, Ballina, NSW) and comparing call variables (minimum and maximum frequency, pulse duration) with those in Fullard *et al.* (1991). Three carcasses found beneath the main roost in the south chamber were also identified and submitted to the Western Australian Museum.

Microclimates determine the suitability of a roost for bats and in some caves, different species roost in different parts of the cave according to their microhabitat preference (e.g. Kunz 1982; Churchill 1991). Temperature was measured in different parts of the cave for part of the study (summer: 15/12/02 – 17/1/03; autumn: 20/4/03 – 10/5/03) using HOBO dataloggers (Onset Instruments Corp.) to characterise the microclimate and determine whether there was a difference between the north and south chambers.

To be able to place the occurrence of a large colony of bats in a south west cave into context, records of bats in caves in the remainder of the region were compiled from a variety of sources, including anecdotal accounts.

RESULTS

Identification

The species occupying the Quininup Lake Cave was identified as the chocolate wattled bat *Chalinolobus morio* (Vespertilionidae) from echolocation call variables (minimum frequency = 51.4 ± 0.8 kHz; maximum frequency = 75.5 ± 3.3 kHz; pulse duration = 4.2 ± 0.7 ms; n = 11; Figure 3). A second species was also identified from echolocation calls during emergence on one occasion (Gould's wattled bat *C. gouldii*; data not shown), but it is more likely that this species was roosting elsewhere and had come to drink from the freshwater pool fronting the cave.

Cluster counts and roost positions

The number of bats recorded on each visit varied (Figure 4), as did their location in the various chambers (Figure 5). Observations from the counts are summarised below:

- Most observations of a 'main cluster' containing most individuals were from the

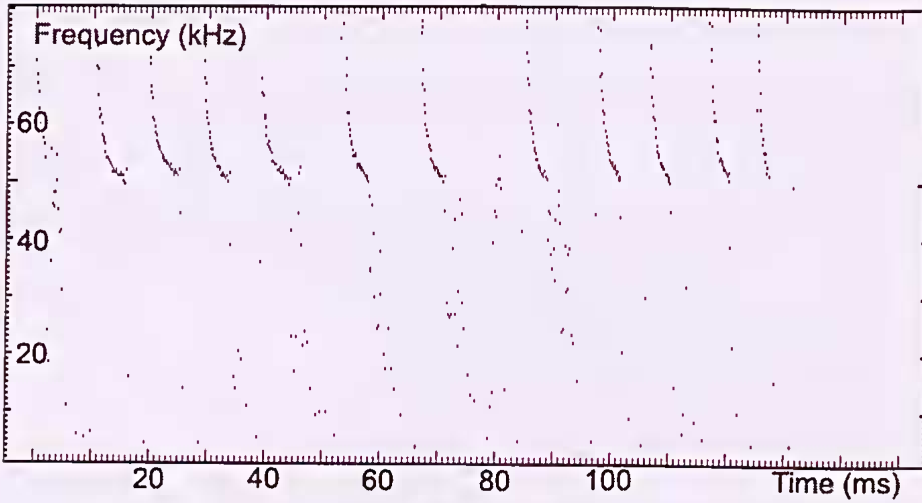

Figure 3. Representative sequence of echolocation pulses recorded from emerging *C. morio* after sunset at the Quininup Lake Cave.

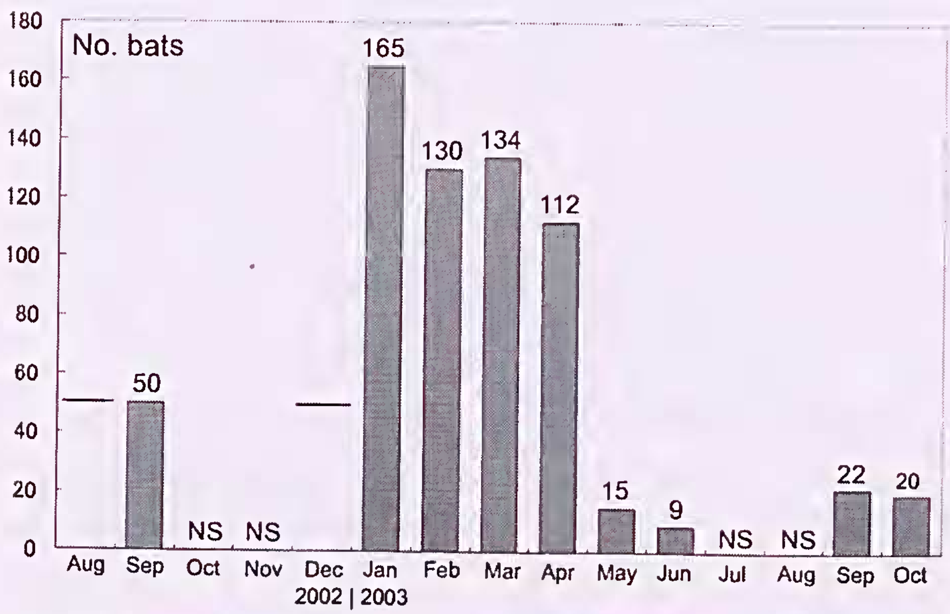

Figure 4. Numbers of bats observed over the study period. Bars in August and December 2002 indicates that a cluster was present somewhere in the cave, however it was not located – bat number was presumed to be high from emergence counts (data not shown). NS: not surveyed.

Figure 5. Numbers and locations of bats observed on the 11 visits. Black circles represent visits where a significant disturbance was presumed prior from the presence of large numbers of candles, sparklers and other items. Numbers in circles represent the number of bat carcasses discovered. Note that while no cluster was observed in August and December 2002, it was likely that it still present somewhere in the cave, since many bats were seen emerging after sunset. Locations of temperature dataloggers are given in the August 2002 map (Ext: External, Nth1: North chamber 1, Nth2: North chamber 2, Sth: South chamber; see Table 1 for averages; Figure 6 for profiles).

south chamber. We observed a 'main cluster' on seven occasions. Though not located, clusters were also likely to be present somewhere in the cave in August and December 2002, since many bats were observed emerging after sunset on these occasions.

- Smaller clusters or individuals were sometimes observed in the north chamber.
- After we observed evidence of human disturbance (large numbers of candles, sparklers, a blanket, other items) in the south chamber (on at least two occasions prior to the May and June 2003 visits), the cluster was not observed until October 2003. This cluster was also much smaller, but of similar size to clusters observed in late 2002.
- Dead bats were observed on two occasions (December 2002 and May 2003; total carcasses 3).
- After May 2003, we observed bats near or on the approach to the doline entrance in the north chamber. We cannot be certain that individuals did not roost in this part of the cave on all occasions where they appear to be absent.

Microclimates

The temperature of both north and south chambers of the Quininup Lake Cave was similar, and relatively stable throughout each 24 hour period, in contrast with the typical daily fluctuation evident at the cave entrance (Figure 6). The degree of daily fluctuation is also evident from the standard deviations in Table 1. Temperatures were similar within the cave in summer and autumn, although the microclimate was c. 1 °C cooler in autumn.

Records of bats in other caves in the south-west

Only seven caves from the Leeuwin – Naturaliste Ridge have a recorded presence of bats (three occasionally, three containing subfossil material), and only the Quininup Lake Cave is currently occupied (Table 2). Six of the caves between Perth and Dongara are thought to be currently used by vespertilionid bats, although in the past it

Table 1. Temperature (°C) variables for different parts of the Quininup Lake Cave (see Figure 5 for location of dataloggers; Figure 6 for profiles).

	Summer		Autumn	
	Mean ± S.D.	Range	Mean ± S.D.	Range
South chamber	17.8 ± 0.3	17.1 – 18.8	18.1 ± 0.3	17.4 – 18.8
North chamber 1	17.5 ± 0.4	16.7 – 18.5	17.9 ± 0.3	17.4 – 18.8
North chamber 2	17.3 ± 0.3	16.7 – 18.1	17.6 ± 0.3	17.1 – 18.5
External	20.3 ± 2.1	15.3 – 26.4	18.8 ± 1.4	15.3 – 22.3

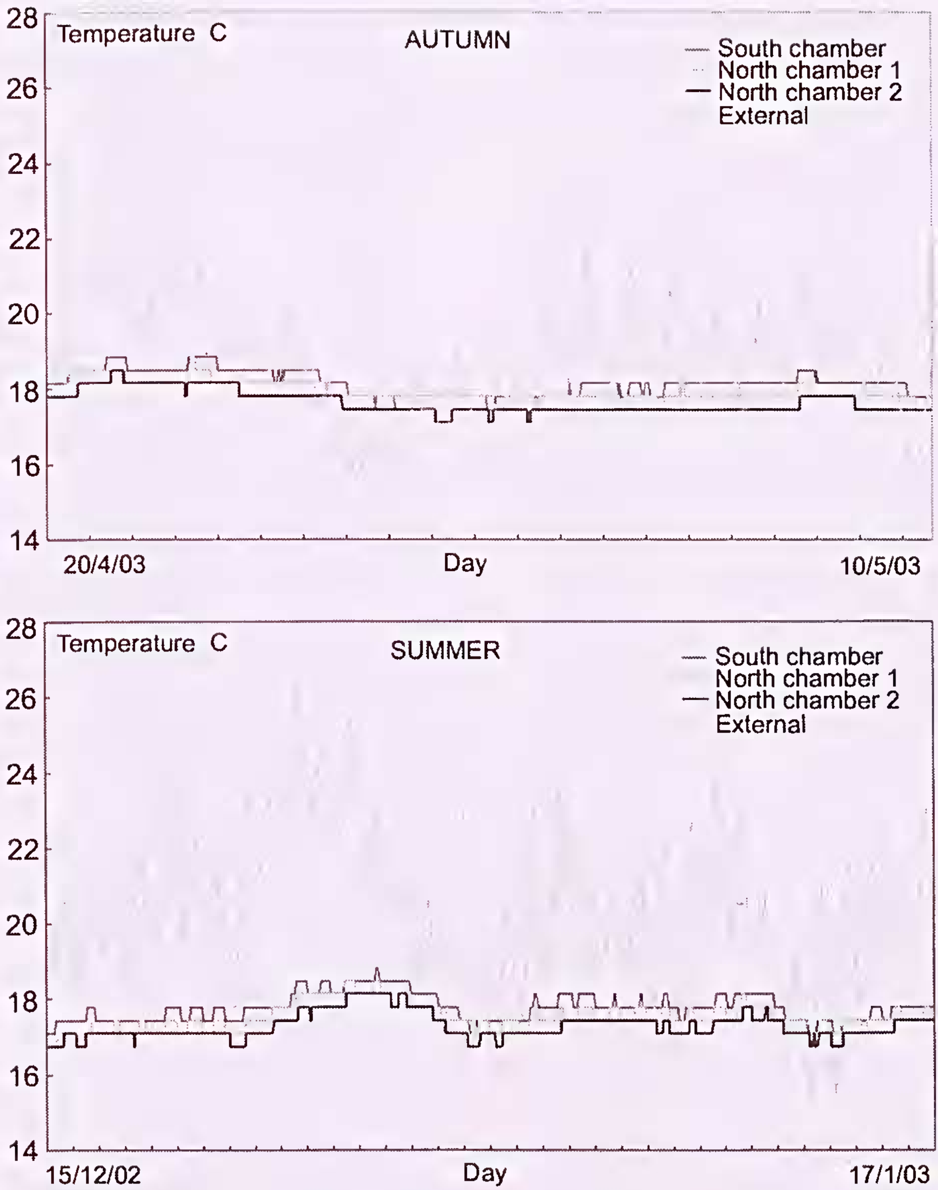

Figure 6. Temperature fluctuations in different parts of the cave, compared with that at the cave entrance (external) and between summer and autumn.

appears that many more (c. 30; Bridges 1975) were used by M. *gigas* (Table 3). However, of these six caves, only four appear to support a large colony (between 20 – 100 individuals). The species present is usually C. *morio* or *Vespadelus regulus*. The cave SH28

Table 2. Records of bats in caves in the Leeuwin-Naturaliste Ridge in the southwest forested region.

Locality	Cave	Species present	Notes	Reference	E[1]
Augusta	Bat Cave	?	–	WASG website[2]	–
Cowaramup	Quininup Lake	*Chalinolobus morio*	Permanent, breeding	This study, Matthews 1985	C
Witchcliffe	Mammoth W138	*C. morio*	On occasions in the past	Matthews 1985 R. Webb pers. comm. See comment by A. Wood[3]	C
Witchcliffe	Nannup W160	*Macroderma gigas*	Subfossil skeletal only	Cook 1960, Matthews 1985	C
Witchcliffe	Devil's Lair W161E	*M. gigas*, *Nyctophilus timoriensis*, *N. geoffroyi*, *Vespadelus regulus*, *C. gouldii*, *C. morio*, *Falsistrellus mackenziei*, *Tadarida australis*	Subfossil skeletal, no present occupation	Baynes *et al.* 1975 Matthews 1985	C
Witchcliffe	Turner Brook (S of Devil's Lair)	*N. timoriensis*	Subfossil skeletal only	Archer and Baynes 1972 cited in Baynes *et al.* 1975	–
Witchcliffe	Dingo cave W171	Vespertilionidae sp.	One fossilised bat	R. Brown pers. obs.	P

1 E: entrance type; C: cave type; P: pothole type.

2 Western Australian Speleologists Group website: http://wasg.iinet.net.au

3 "Occasionally a group of bats in the [Mammoth] cave – not far from the entrance where there was still some light – always in the same area. No longer come into that part of the cave after the old timber gate was replaced in c. 1994. Other reports of them in the 'exit' section of the cave after the entry gate had been replaced." (A. Wood pers. comm. to KNA)

near Cervantes apparently also had a colony in the past (Matthews 1985), but current occupancy could not be verified in the present study. Nullarbor records were not compiled in the present study.

DISCUSSION

Within the 680 km between Dongara and Augusta, only five caves appear to support a colony of bats currently, and only one in the Leeuwin – Naturaliste Ridge. This colony in Quininup Lake Cave is visited regularly by authorised cavers and unauthorised visitors, but still persists. We provide some circumstantial evidence that overall bat occupancy, and roost position in the cave might change according to a 'significant' disturbance. The cluster of bats normally observed in the southern chamber disappeared for several months following the discovery of large numbers of candles and other items, and individuals were observed for the first time (in this study) in parts of the northern chamber. It is difficult to determine with certainty if movement in the cave and cluster size is related to disturbance or natural seasonal patterns. Regular visitation was a confounding factor and the data is suggestive of both. Our data is limited: the study was short term (one year); we chose low impact techniques to observe the bats and thus were not able to collect information on reproduction and sex ratio; the cave was visited once on most but not all months. Therefore, the amount of information from the surveys limits our conclusions. However, it does indicate that the southern chamber, while not used exclusively, seems to be preferred by the bats. This is perhaps fortuitous since most high quality decorations and other interesting features (besides the bats) are present in the northern chamber, providing the opportunity for managing the two chambers for separate activities (caving and conservation).

None of the bat species that occur in the south west caves are included in a category of special protection under state or federal legislation, or in the Department of Conservation and Land Management's Priority Fauna List (see also Duncan *et al.* 1999). However, we argue that the occurrence of bat colonies in south west caves is a natural feature worth preserving, quite apart from any consideration of the contribution that such colonies make to local demes. The simple fact that it is unusual to find bat colonies in caves in this large area increases their value. The two main occupying species (*C. morio* and *V. regulus*) probably roost in tree habitats in the same areas, although such roosts may not be capable of supporting the same number of individuals (though up to 100 females of *V. regulus* are often observed in tree roosts, Churchill 1998). Secondly, several caves are

Table 3. Records of bats in caves between the Perth metropolitan area and Dongara, and east to Moora. Further references may be found in Matthews (1985).

Locality	Cave	Species present	Notes	Reference	E[1]
Cervantes	7 caves*	*M. gigas*	Subfossil guano and skeletal	Bridge 1975	–
Cervantes	Super SH1	?	Extensive guano	Matthews 1985	C
Cervantes	Weston SH2	?	Extensive guano	Matthews 1985	C
Cervantes	Army SH11	?	Extensive guano	Matthews 1985	C
Cervantes	Taranakite SH15	?	Extensive guano	Matthews 1985	P
Cervantes	Brown Bone SH17	?	South of Cervantes, 4 km NW of The Pinnacles, 50–100 bats	J. Tonga pers. comm.	C
Cervantes	Cadda SH18	?	Extensive guano	Matthews 1985	C
Cervantes	Princes SH23	?	Extensive guano	Matthews 1985	P
Cervantes	SH28	?	Many bats	Matthews 1985	–
Cervantes	Kinenabbra SH40	?	Extensive guano and skeletal	Matthews 1985	P
Coorow	Coorow M1	*M. gigas*, other unidentified	Subfossil guano and skeletal, extensive, occasional bats	Bastion 1959; Bridge 1975; Matthews 1985	C
Enneaba	Stockyard Tunnel E1	*C. morio*	Sometimes observed	Matthews 1985; pers. comms.	C
Enneaba	Stockyard E3	*C. morio*	Colony of c. 100 bats often observed. c.60 bats on March 2003	Matthews 1985 J. Murray pers. comm.	C
Enneaba	Arramall E22	*M. gigas*	Subfossil	J.W.J Lowry, WASG website[2]	C
Enneaba	Weelawadji E24 (Jankara)	*M. gigas*, *C. morio*, *C. gouldii*, *V. regulus*	Subfossil skeletal of *M. gigas*, extensive guano, locked, 20 unidentified vespertilionid bats observed March 2003	J.W.J Lowry, WASG website[2] J. Murray pers. comm.	C

Enneaba	Weelawadji West E52	*M. gigas*	Subfossil skeletal	Matthews 1985	P
Enneaba	6 or fewer caves*	*M. gigas*	Subfossil guano and skeletal	Bridge 1975	–
Jurien	Gooseberry J1	*C. morio*	Maternity site	Matthews 1985	–
Jurien	Drovers J2	*M. gigas*, *C. morio*	Subfossil skeletal, locked, previously large colony of *C. morio*, now extinct	Matthews 1985 R. Webb, WASG website[2]	C
Jurien	Moorba J3	?	Old guano mine, occasional sightings	Matthews 1985	P
Jurien	Hastings J4	*M. gigas*	Subfossil guano and skeletal	Bridge 1975, Matthews 1985	P
Jurien	5 or fewer caves*	*M. gigas*	Subfossil guano and skeletal	Bridge 1975	–
Ledge Point	2 caves*	*M. gigas*	Subfossil guano and skeletal	Bridge 1975	–
Mimegarra	Wedges	*M. gigas*	Subfossil guano and skeletal	Bridge 1975	–
Yanchep	Yanchep YN16	?	Extensive guano, formerly mined, now inappropriately gated	Matthews 1985	C
Yanchep	YN85	?	Formerly contained bats	Matthews 1985	–
Yanchep	Zenal's YN92	?	Formerly contained bats	Matthews 1985	–
Wanneroo	1 cave	*M. gigas*	Subfossil guano and skeletal	Bridge 1975	–
Watheroo	2 caves	*M. gigas*	Subfossil guano and skeletal	Bridge 1975	–
Yanchep	3 caves*	*M. gigas*	Subfossil guano and skeletal	Bridge 1975	–

[1] E: entrance type; C: cave type; P: pothole type.

[2] Western Australian Speleologists Group website: http://wasg.iinet.net.au

* many of the caves mapped by Bridge (1975) were not named by him. We summarised the total numbers for each locality from this paper. Some of these might actually appear in table entries from other references. Bridge states that about 30 caves between Perth and Dongara contained guano and/or skeletal material from *M. gigas*.

recognised as maternity sites, which further underlines their importance.

Most bat species tend to roost either in trees or in caves (or analogous man-made structures), but not both (ABS 2000a, b). The bat species that occur in the south west region generally roost in trees during the daytime (Fullard *et al.* 1991; Churchill 1998). *C. morio* and *V. regulus* are the only south west WA bats that roost in significant numbers in both habitats. They occur in forest, woodland, mallee and shrublands, and roost in a wide variety of structures including tree hollows, houses, exfoliating bark, martin nests, culverts, bridges, and caves on the Nullarbor in the case of *C. morio* (Churchill 1998). Thus, a third consideration when determining the value of these occurrences is the ecological novelty of observing mainly tree-roosting bats occupying caves.

The relatively stable temperature recorded in both autumn and summer in both chambers of Quininup Lake Cave highlights the importance of structures as roosts. While we were unable to collect data on reproduction, it is well established that many species choose roost microclimates with a stable, and often relatively high temperature and relative humidity during parturition and lactation (Kunz 1982). Females of *C. morio* generally form clusters, while males roost alone (Churchill 1998). We have observed both large clusters and individuals roosting singly in Quininup Lake Cave, but we were unable to determine the sex of bats without their capture.

Interestingly, seven caves of the total compiled in Tables 2 and 3 had pothole type entrances. Generally, but not exclusively, bats are observed in structures with classic tunnel type entrances (K.N. Armstrong pers. obs.). All of those that currently contain vespertilionid bat colonies have cave type entrances. Many of the caves with evidence of *M. gigas* had pothole entrances, suggesting that this species is not limited by such a structure (this observation was also made by KNA at Nullagine). If pothole entrances limit occupancy by other species, this would be one factor that explains the absence of bats in caves with large subterranean spaces and supposedly suitable microclimates for roosting.

It is beyond the scope of the present study to discuss management issues in depth, however we provide the following recommendations for serious consideration and budget allocation by the land managers:

Quininup Lake Cave:

- Prohibit entry to the southern chamber by all visitors;
- Reduce the number of permits, and limit group sizes;
- Removal or relocation of the car park;
- Increased ranger visition and additional signage (i.e.

increased presence by the land manager);

- Prosecution of illegal entrants (through a test case);
- Monitor visitation in the southern chamber with light-detecting dataloggers to determine if visitation has decreased, and review management strategies accordingly;
- Consider the addition of an appropriately designed and installed gate over the main entrance of the south chamber. Specialist advice would need to be sought, and a modest budget allocated by the land manager. This is considered to be a last resort in the event that the other strategies above are not sufficiently effective.

Perth – Dongara region:

- Remove or modify inappropriate gates on Drovers and Yanchep Caves;
- Reduce the number of permits, and limit group sizes to caves with significant colonies of bats (Brown Bone Cave SH17, Stockyard Cave E3, Weelawadji E24, Gooseberry J1);
- Identify all bat species utilising the caves. Specialists would need to be consulted;
- Ask authorised cavers to report back on approximate colony size, information to be compiled by the land manager;
- Provide information regarding appropriate behaviour near bat colonies to authorised cavers entering the four caves SH17, E3, E24 and J1;
- Investigate cave SH28 for bat colony occurrence;
- Compile further information for future management consideration.

We recognise that the present study has probably missed some information on bat occurrence in the south west caves. However, we also recognise that of the dozens of caves between Augusta and Dongara, only a minimum of five are currently known to support bat colonies of significant size, and the discovery of more is unlikely. This study represents a foundation for the compilation of further information and design of *bona fide* scientific study.

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